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TELEMETRY RESULTS WITH THE M456A1E2 PROJECTILE--SERIES 3

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October 1981

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BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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In-Flight Measurements
FFAIS DC Voltage Measurements
AC Voltage Measurements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (caw/lcb)

Four high-explosive anti-tank projectiles, M456A1E2, were instrumented to measure various a.c. and d.c. voltages in the piezoid/switch/fuze circuit during flight. Three of the four rounds transmitted. Experimental results show a.c. signals present on the FFAIS and the detonator. The resistance of the detonator was measured and determined to be 600-900 ohms indicating that the fuze was armed and detonator intact. A d.c. voltage of 650 volts on the FFAIS was measured for one round and 0.0 volts d.c. for the other two rounds. (Continued)

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20. ABSTRACT (Continued):

There are no data to indicate why a zero-volt level exists. A survey of previous telemetry results reveals that the zero-volt level at the FFAIS existed on a total of three of six rounds. The absence of a d.c. voltage on the FFAIS could result in a non-functioning of the M456A1E2 projectile on glancing impact.

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I. INTRODUCTION

An instrumented flight test of four M456A1E2 projectiles was conducted at the NASA launch facility at the Wallops Flight Center in Virginia during the week of 14 January 1980.

The M456A1E2 is a high-explosive anti-tank projectile that uses a piezoelectric device (piezoid) to generate an impulsive current upon impact. This impulsive current ignites a detonator which in turn sets off a shaped charge explosive. The M456A1E2 has a full-frontal-area-impact switch (FFAIS) which is used to enhance the effectiveness of a projectile against targets at high angles of incidence or against unusual armor designs. The FFAIS consists of a contoured aluminum shell with plastic insulation which conforms to the spike-nose shape of the M456A1E2. It forms a capacitance between the piezoid and the spike nose and stores a charge developed during launch by the piezoid. During flight the stored charge on the FFAIS prevents the charge on the piezoid from dissipating. On impact the FFAIS shorts to ground and permits the piezoid charge to flow through the detonator.

The test described in this report was a continuation of a similar telemetry test conducted in August 1979 at the NASA facility at Wallops Island. The four instrumented M456A1E2 projectiles were equipped to measure various voltages in flight without disturbing the electrical parameters of the piezoid/FFAIS circuits. The purpose of the firings was to characterize the behavior of the M456A1E2 electronic components in the gun tube and in the vicinity of the muzzle after exit. It was hoped that the measurements would reveal a voltage or voltages or an event that might be the source of an occasional premature functioning of the M456A1E2. The four rounds were fired at maximum charge with a velocity of 1173 m/s. Three of the four rounds had r.f. transmission. The remaining round experienced battery failure milliseconds before launch. This report describes the experiment and presents the results obtained from the three rounds which had r.f. transmission.

II. INSTRUMENTATION

A. FFAIS/Piezoid/M509A1 Electrical Circuit

The full frontal area impact switch is a device which consists of a plastic-coated aluminum shroud installed on the spike nose of the M456A1E2 projectile. The shroud is separated from the spike by plastic spacers and a capacitance is formed between the spike and the shroud. One side of the piezoid, located in the spike, is attached to the FFAIS through a spring/slide contact. The other side of the piezoid is attached to the M509A1 fuze with a long steel cable. The FFAIS was modified for this measurement by attaching a second steel cable to the FFAIS, and hence to the FFAIS side of the piezoid, so that the voltage across the FFAIS could be measured. Figure 1 shows a schematic of the basic piezoid/FFAIS/fuze circuit.

Briefly, the operation of the FFAIS/piezoid/M509A1 circuit is as follows. Prior to firing, the detonator in the M509A1 device is not in the circuit. Upon launch, the piezoid produces a charge in response to the acceleration forces. At about 22,000 g's, a flexible bar in the piezoid shorts the piezoid and discharges the FFAIS. This short remains until the acceleration falls below 22,000 g's. The piezoid now produces a charge of opposite polarity to the initial charge. The FFAIS capacitance then charges until the projectile exits the gun tube. When the projectile exits the gun the charging cycle ends and the final charge is stored on the FFAIS/piezoid interface until impact occurs. After muzzle exit, the safety and arming mechanism in the M509A1 fuze mechanically places the detonator in the circuit. This occurs from 9 to 30 metres from the muzzle.

For the purpose of this test, the piezoid was fabricated so that a positive charge would be stored on the FFAIS upon muzzle exit. The piezoids used in these tests did not use any diodes or other components designed to block a.c. voltages. M509A1 fuze mechanisms were used in these tests and were modified by replacing the powder charge with an aluminum block, making them functional but inert. The live detonator was not removed from the M509A1 fuze.

B. <u>On-Board Measurement Circuits</u>

The test was designed to measure voltages at various points both while the projectile was in-bore and after the projectile exited the gun. S-band telemetry transmitters (2,250 MHz) were used on two rounds in an attempt to obtain r.f. reception while in the bore. L-band telemetry transmitters (1,520 MHz) were used on the other two rounds. The L-band transmitters have more output power available and were used in order to enhance reception after the projectile exits the gun tube. However, at L-band frequencies the gun tube will squelch the r.f. transmissions once the projectile starts moving. The following in-flight measurements were to be made: (1) d.c. voltages across the FFAIS; (2) a.c. voltages across the FFAIS; (3) a.c./d.c. voltage measurements across the bleeder resistor (before arming) and across the detonator (after arming) in the fuze; and (4) a.c./d.c. voltage measurements across a 300-ohm resistor in series with the detonator.

(1) <u>FFAIS measurements</u> included a high-level d.c. voltage measurement circuit and a low-level a.c. circuit. The schematic of the FFAIS measurement circuit is shown in Figure 2.

A capacitive voltage divider was used to measure the d.c. switch voltages. It was designed to divide the switch voltage by approximately 500. A high-input-impedance (10^{12} ohms), voltage-follower amplifier (gain = 1) was used to minimize draining of the charge across the FFAIS by the measurement circuit. High-voltage ceramic capacitors were used in the voltage divider. A g-switch was used to keep the switch capacitance and the input to the voltage-follower shorted to ground until the round was launched. This was necessary because the rounds were turned on before loading into the gun. Because of the high-input impedance of the amplifiers, their output voltages would tend to drift after the unit was turned on and before it could be launched (approximately 5-15 minute time interval). Therefore, the g-switch insured that a proper initial amplifier condition was provided for the measurement. The g-switch opens upon launch at several hundred g's.

Even with a high-input-impedance amplifier, it is difficult to eliminate interference between the measurement circuit and stored charges across the FFAIS. Stray capacitances in the encapsulating material and even printed circuit board impedances can provide a leakage path to ground. Therefore, after the units were encapsulated, the decay rates of the d.c. circuits were measured. This was accomplished by momentarily applying a battery (284 volts d.c.) to the switch and monitoring the output of the d.c. amplifiers with a digital oscilloscope. Figure 3 shows the time decay of the switch voltage for unit 5 (Round E1-9944) for this test. The voltage decays to about 70 percent of the initial value in about 40 seconds. In the region of interest, which is within 0.5 second after the impulse, there is little significant decay.

A second capacitive voltage divider in the divide-by-three-arrangement was used across the FFAIS for a.c. measurements. The divider output was a.c. coupled into a high input-impedance amplifier in a voltage-follower configuration.

(2) Detonator-fuze measurements included two amplifier circuits (see Figure 4). One circuit, called the detonator circuit, used a resistive voltage divider set at a divide-by-three level to measure a.c. or d.c. voltage across the M509A1 fuze. In-bore this circuit would be in parallel with a bleeder resistor in the M509A1 fuze. In-flight, after the fuze arms, this circuit would then be across the detonator contained in the M509A1 fuze. The second circuit, called the differential circuit, on the fuze side of the piezoid measures the a.c. or d.c. voltage across a 300-ohm resistor placed in series with the M509A1 fuze. This resistor normally is not part of the circuit. The purpose of these circuits was to detect fuze arming, provided data were acquired early enough, and to measure the impedance of the detonator after arming occurs.

(3) A schematic of the telemeter circuit is shown in Figure 5. Five voltage-controlled-oscillators (VCO), four for the voltage measurements and the fifth for a reference signal, were mixed and made to modulate a radio-frequency transmitter operating at S-band (2,200 MHz) or L-band (1,520 MHz). A 100-Hz reference signal was included as part of the data circuit in order to determine whether or not voltage spikes that occur in the data are real or are merely noise caused by interference in the telemetry link.

III. GROUND INSTRUMENTATION

A. M68 Tube Instrumentation

The M68 tube was instrumented with a strain gage located on the outer surface of the tube, 19.4 cm from the muzzle end. The strain gage formed one leg of a bridge circuit. A voltage pulse is produced when the projectile passes by the strain gage patch. The voltage pulse provides a reference time assumed to be the time at which the projectile exits the gun tube.

The 105mm cartridge cases were instrumented with strain gage transducers in order to obtain breech pressure profiles for each round. The transducers were calibrated for resistance versus pressure and each formed one leg of a bridge circuit. In addition, each cartridge case had copper-crush gages that would provide leak pressures.

Smear photographs were taken for each round to observe structural integrity of the projectiles.

B. Telemetry Instrumentation

Telemetry coverage was provided both by BRL and by the NASA telemetry group of Wallops Flight Center. Coverage was provided at two sites, main base and at the gun site. The main base receiving station is located approximately 15 kilometers from the firing site at Wallops Island, Virginia. NASA also provided a local telemetry station at the firing site. The BRL telemetry instrumentation was also located at the firing site. Data from the gun instrumentation were recorded at the local stations only. NASA also provided range timing at both telemetry locations.

IV. TEST RESULTS

The four M456A1E2 projectiles, fired at the Wallops Flight Center during the week of 14 January 1980, were all launched at maximum charge with a velocity of about 1,173 m/s, at a quadrant elevation of 20 degrees. Projectile flight weight was 10 kilograms. Expected time of flight for these conditions was about 32 seconds with a range of 8,200 meters. Table I summarizes the test results.

TABLE I. TEST RESULT SUMMARY

Round No.	Transmitter Frequency (MHZ)	Comments
E1-9942	1520	(1) * Acquired data at T_e + 55 millisecond (2) FFAIS d.c. voltage = 0.0 volts (3) a.c. voltage signals on other circuits except for differential channel
E1-9943	1520	(1) No results. Battery failure occurred milliseconds before launch.
E1-9944	2250	(1) R.F. shifted 2 MHZ upon launch. (2) Acquired data at T_e + 1.26 seconds (3) FFAIS d.c. voltage = 650 volts initially (4) a.c. voltage signals present on all other channels.
E1-9945	2250	(1) R.F. shifted 4 MHZ upon launch. (2) Acquired data at T_e + 1.5 seconds (3) FFAIS d.c. voltage = 0.0 volts (4) a.c. voltage signals present on all other channels.

* T_e = muzzle exit time

Table II lists the peak breech pressures measured for these rounds.

TABLE II. PEAK BREECH PRESSURE

Round No.	Peak Pressure
E1-9942	438 Mpa
E1-9943	394 Mpa
E1-9944	416 Mpa
E1-9945	415 Mpa

Figures 6-9 are plots of the breech pressure profiles obtained with the strain gage transducers located in cartridge cases. The peak pressures correspond to peak accelerations of from 34,000 to 38,000 g's.

A. E1-9943

Round E1-9943 was the second round fired. There was a delay in getting the round loaded into the gun tube after the telemeter was turned on. Prior to launch the frequency of the transmitter started to drift indicating that the power supply voltage was decreasing. Figure 10 is a plot of the AGC signal output of the telemetry receiver versus time, where zero-time is muzzle exit time. The AGC signal shows a loss of signal at 12.5 milliseconds before muzzle exit. A comparison with Figure 7 (breech pressure) indicates that signal was lost approximately 6 milliseconds before the projectile started moving. Thus, a failure occurred in the power supply rather than in a component during launch.

B. E1-9944

Data were obtained on all VCO channels for E1-9944. The transmitter for this round was at S-band (2,250 MHZ). It was hoped that data could be obtained in-bore as well as in-flight for this round and for E1-9945. However, the frequency of the transmitter shifted 2 MHZ upon launch and data were not obtained until 1.26 seconds after muzzle exit. This is well after the time it takes for the M509 fuze to arm. Therefore, the actual arming of the fuze was not detected. However, as shown later, arming did occur and detonator was intact.

The d.c. voltage across the FFAIS for E1-9944 is shown in Figure 11. The initial voltage is about 650 volts. The voltage decays to about 530 volts in the first five seconds and much slower thereafter. Figure 12 is a comparison of the rate of decay of the voltage across the FFAIS between flight data (Figure 11) and preflight test data (Figure 3). The decay rate of the flight data is almost identical to that in the preflight test after about five seconds. The preflight data was obtained by momentarily impressing a voltage (300 v d.c.) across the FFAIS. The flight data, of course, results from an electromechanical response of the piezoid to launch accelerations. The difference between the decay rates in the first five seconds could be produced by the mechanical response of the FFAIS or the piezoid to launch accelerations (for example, a slowly changing capacitance of the FFAIS after launch).

Plots of a.c. voltage signals, in two millisecond intervals, are presented in Figures 13-21. These represent the voltages present at 1.26 seconds, 10.1 seconds, and 20.1 seconds after muzzle exit. The plots illustrate the changing nature of the a.c. voltages. Figures 13-15 show signals from the circuit across the FFAIS. Figures 16-18 are the signals across the fuze and Figures 19-21 are for the series resistor. Examination of these figures show that, in general, the a.c. signals are complex waveforms whose amplitude and frequency content varies with time. Peak amplitudes vary from 0.2 volt to 0.8 volt across the FFAIS and from 0.05 volt to 0.150 volt for the detonator. Peak voltage amplitudes across the 300-ohm series resistor varies from 0.180 volt to about 0.500 volt. Figures 22-24 are plots of the spectral contents of the waveforms across the FFAIS, fuze, and series resistor, respectively, at 10.1 seconds after muzzle exit.

The resistance at the output of the M509A1 fuze can be obtained from the relative amplitudes of the voltage signals at the detonator and series-resistor circuits. If the fuze had not armed, the detonator circuit would be across the bleeder resistor which is about 100 Kohms. If the detonator is in place and the fuze is armed, then the detonator circuit will be across a low impedance. Because of phase differences between the detonator and series resistor circuits and VCO channels, instantaneous voltages cannot be used to calculate the detonator resistance. However, the signals at the detonator and the 300-ohm series resistor can be averaged over a short period of time and then used to calculate the detonator resistance. Table III lists some rms voltages for the detonator and the series resistor circuits for E1-9944. The resistance at the fuze output terminals is calculated from the expression:

$$\text{Resistance} = \frac{300 * (V_{DET})_{RMS}}{(V_{SERIES})_{RMS}}$$

The averages were calculated over 2-millisecond samples at various points in time.

TABLE III. FUZE RESISTANCE FOR E1-9944

Time (sec)	Detonator (rms volts)	Series (rms volts)	Resistance (ohms)
1.26	.069	.028	751
3.50	.085	.032	810
5.50	.113	.040	846
6.50	.104	.035	906
8.50	.101	.036	856

These calculations are approximate in that they are obtained by averaging a complex waveform over short time intervals. It would be more reasonable to average individual frequency components over short time intervals. This will be done and presented in a later report. However, it is clear that the fuze impedance is low, in the range of 700-900 ohms, showing that the fuze is armed with the detonator in place.

C. El-9942 and El-9945

Figures 25 and 26 are the AGC signals for El-9942 and El-9945, respectively. Round El-9942 was at L-band and data were first acquired about 55 milliseconds after muzzle exit. El-9945 was at S-band and due to a 4 MHz frequency shift upon launch, data were not acquired until 1.5 seconds after muzzle exit.

Figures 27 and 28 are plots of the d.c. voltage on the FFAIS for El-9942 and El-9945 both before and after the projectile was launched. It is seen that 0.0 volts exist on the FFAIS after the projectile exits the gun tube for both of these rounds. It is unlikely that the amplifier failed. Amplifier failures result in non-zero voltages since the output is usually at the positive or negative power supply voltage. A short circuit across the FFAIS does not exist because a.c. signal voltages are present on the a.c. circuit across the FFAIS. Figures 29-31 are plots of the a.c. voltages across the FFAIS at 1 second, 5 seconds, and 10 seconds for El-9942. Figures 32-34 are similar plots for El-9945 at 1.5, 5, and 10 seconds. These waveforms are similar in nature to those for Round El-9944. That their amplitude and frequency content are changing is evidence that the FFAIS is not shorted. Likewise, a permanent short across the piezoid does not exist since there would be no source for the a.c. signals for these two rounds if this were the case.

Round El-9942 did not have a VCO channel to measure voltages at the 300-ohm series resistor. However, it did have a measurement circuit across the fuze. Round El-9945 had both circuits. Figures 35-37 are plots of the voltage signals across the fuze for El-9942 at various times after muzzle exit. Figures 38-40 are similar plots for El-9945 and Figures 41-43 are plots of the voltage waveform across the 300-ohm series resistor.

It is unfortunate that the frequency of the transmitter shifted for Round El-9945 or a complete history of the d.c. voltage on the FFAIS could have been obtained. However, as with Round El-9944, the fuze impedance can be calculated from the voltage signals across the detonator and series resistor circuits. The results are presented in Table IV.

TABLE IV. FUZE RESISTANCE FOR E1-9945

Time (sec)	Detonator (rms volts)	Series (rms volts)	Resistance (ohms)
1.5	.047	.025	572
2.5	.074	.035	643
3.5	.074	.035	643
5	.082	.031	804
6	.091	.039	709
7	.105	.038	840
8	.105	.038	840
9	.120	.047	776

The resistance at the fuze output terminals for E1-9945 is from 550-850 ohms. This shows that the fuze did arm and that the detonator was intact.

V. DISCUSSION

Data were obtained from three of the four instrumented M456A1E2 projectiles. However, a non-zero d.c. voltage on the FFAIS is present on only one of the three rounds, round E1-9944. With the data available it is not possible to isolate the reason for the zero-volt FFAIS measurement on rounds E1-9942 and E1-9945. If the voltage dropped to zero because of some catastrophic event, it must have occurred before the fuze armed since the measurements indicate, at least for Round E1-9945, that the detonator remained intact. A malfunction of the shorting bar in the piezoid could account for the zero-volt levels. If the shorting bar did not function at all then the d.c. voltage on the FFAIS would be zero by the end of the charging cycle. It is also possible that the g-switch slug (Figure 2) rebounded during the charging cycle and shorted out the FFAIS. To explain the continued a.c. signals after launch would require a double rebound of the g-switch, however, and this seems unlikely. Moreover, an earlier test series at reduced charge showed a 0.0 volts measurement across the FFAIS at launch and no g-switch was used during that initial measurement program.

This series was the third series of instrumented M456A1E2 projectiles fired at Wallops Island, Virginia. A total of twelve instrumented rounds have been fired. Data have been obtained on six of those rounds. Table V summarizes the results of the measurements of the initial d.c. voltage on the FFAIS for those six rounds.

TABLE V. SUMMARY: FFAIS D.C. VOLTAGE

Date	Round No.	FFAIS d.c. voltage
June 77	E1-9114*	0.0
	E1-9115	-460
August 79	E1-9937[1]	+300**
January 80	E1-9942	0.0
	E1-9944	+650
	E1-9945	0.0

* *Fired at reduced charge.*
** *Persisted for 0.8 second after muzzle exit and then went to zero somewhere between 1 and 10 seconds.*

1. *Mermagen, W.H. and Clay, W.H., "In-Flight Experiments with the M456A1E2 Heat Projectile." Ballistic Research Laboratory ARRADCOM Report No. ARBRL-MR-2902, December 1977. AD B025307L.*

On only two rounds, E1-9115 and E1-9944, was there a d.c. level that persisted for a time greater than one second after muzzle exit. Although six rounds is not a large statistical sample, it is significant that on half those rounds the d.c. level across the FFAIS is zero. Three possible explanations for the zero-volt condition at the FFAIS suggest themselves: (1) the shorting bar failed to function properly in the piezoid; (2) the FFAIS voltage was discharged due to other mechanisms early in the flight; (3) the measurement circuit did not function properly. Now, the measurement circuit did continue to show low-level a.c. signals during all flights and the components used in the circuit across the FFAIS are used elsewhere in the system and did not fail. The FFAIS could discharge early in the flight due to some unknown mechanism, but this would have to occur before fuze arming takes place since the rms observations show the detonator to be intact during the two flights with zero FFAIS volts. Round E1-9937 lost the FFAIS voltage somewhere between 1 and 10 seconds and a detonator was used on this test. With the present evidence, it seems probable that some malfunction occurred in the piezoid, perhaps the shorting bar did not operate as designed, to give a zero voltage on the FFAIS.

VI. SUMMARY

Four instrumented M456A1E2 rounds were fired at the NASA launch facility at Wallops Island, Virginia during the week of 14 January 1980. Data were received on three of the four rounds. Zero-volt d.c. levels on the FFAIS were measured on rounds E1-9942 and E1-9945. Approximately 650 volts were measured on the FFAIS for round E1-9944. A.C. signals were present on the FFAIS for all three rounds and on circuits in parallel with and in series with the M509 fuze. The a.c. levels observed and the frequency content are about the same as measured on previous tests. Measurements from the a.c. signals present in the fuze circuits indicate a resistance of 700 - 900 ohms at the fuze terminals indicating that the fuze is armed and the detonator is intact for rounds E1-9944 and E1-9945. A comparison of these rounds with previous telemetry tests on the M456A1E2 shows that in 50 percent of the rounds for which data exists the d.c. level on the FFAIS is zero. The absence of a d.c. voltage on the FFAIS could result in a non-functioning of the M456A1E2 projectile on glancing impact.

Additional telemetry tests will be conducted with emphasis upon acquiring data in the gun tube and early in the flight so that a complete history on the operation of the piezoid can be obtained. Several tests will also be done with new diodes for the piezoid to determine their effectiveness in removing a.c. signals.

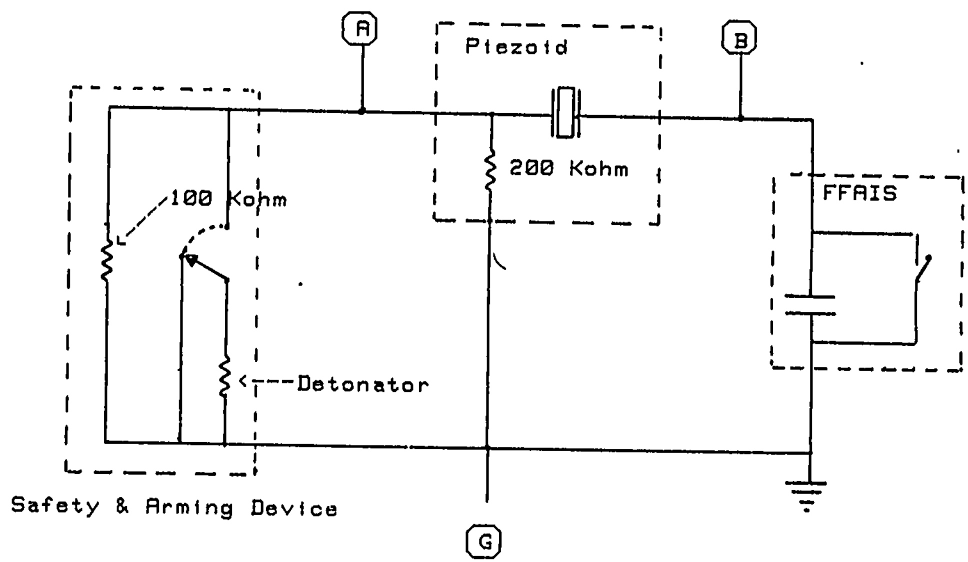

Figure 1. Schematic of the electrical circuit for the M456A1E2 projectile.

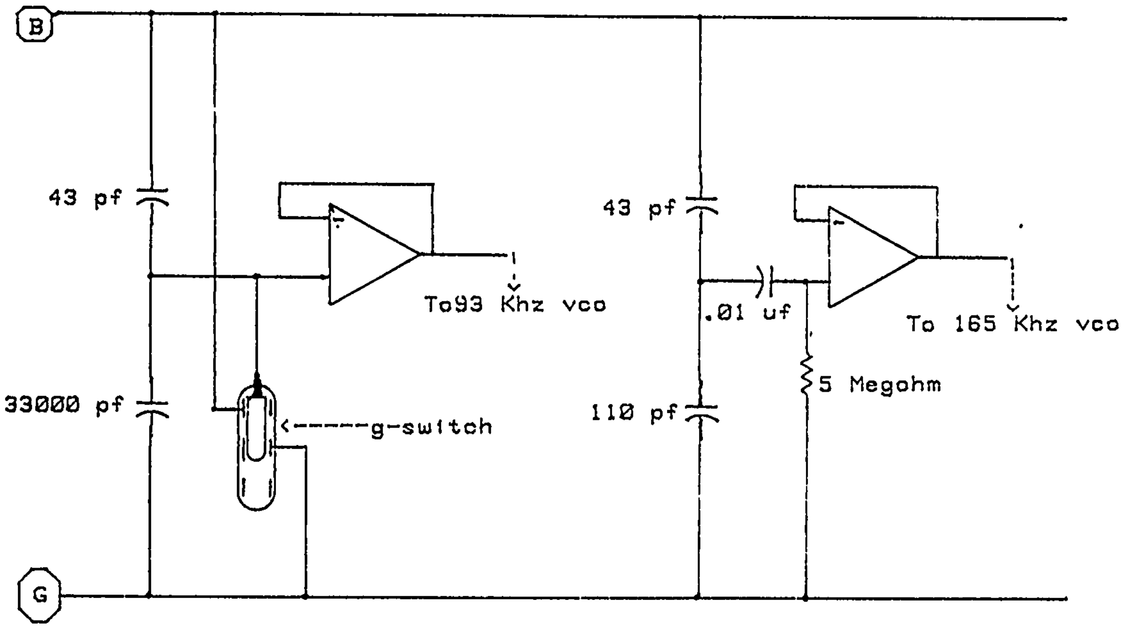

Figure 2. Schematic of the measurement circuits across the FFAIS.

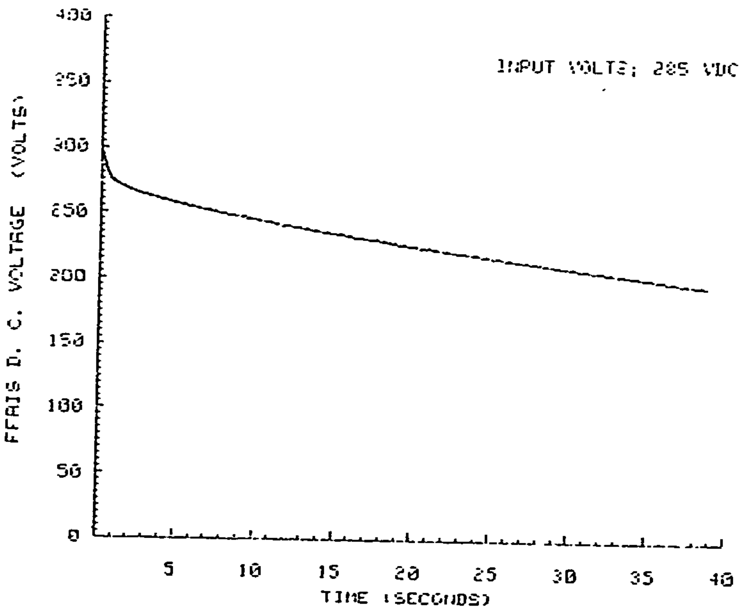

Figure 3. Voltage decay for divide-by-500 for E1-9944 (after encapsulation).

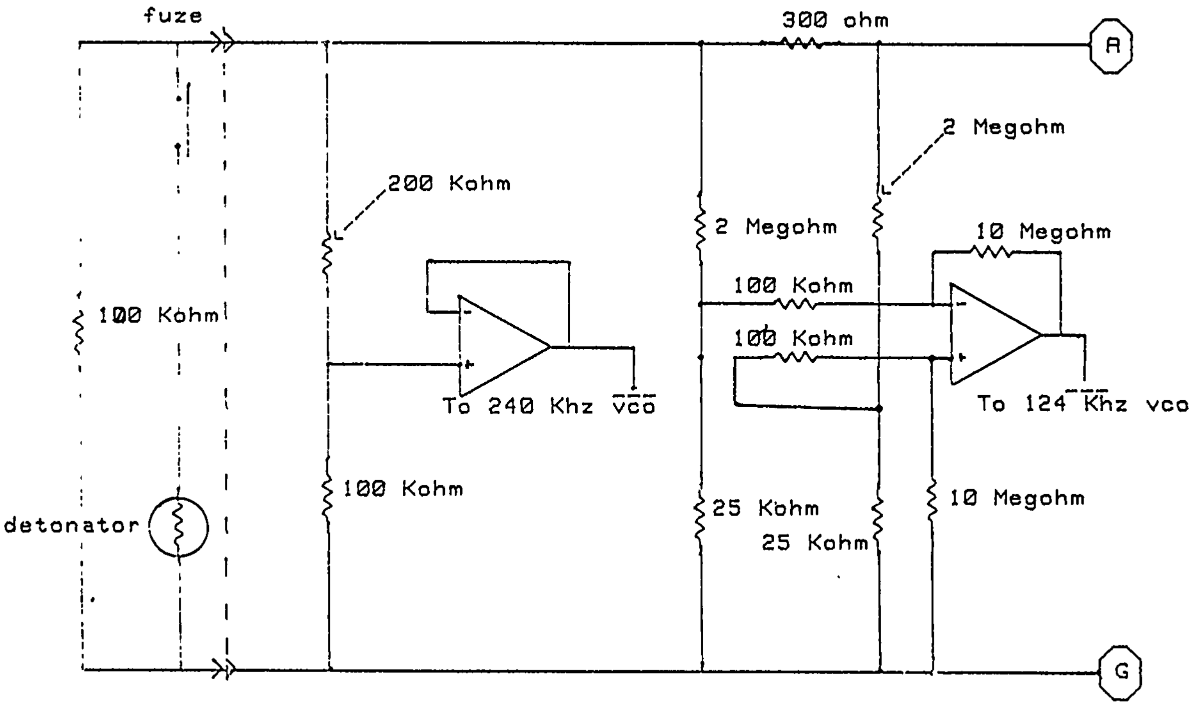

Figure 4. Schematic of measurement circuits across the M509 fuze.

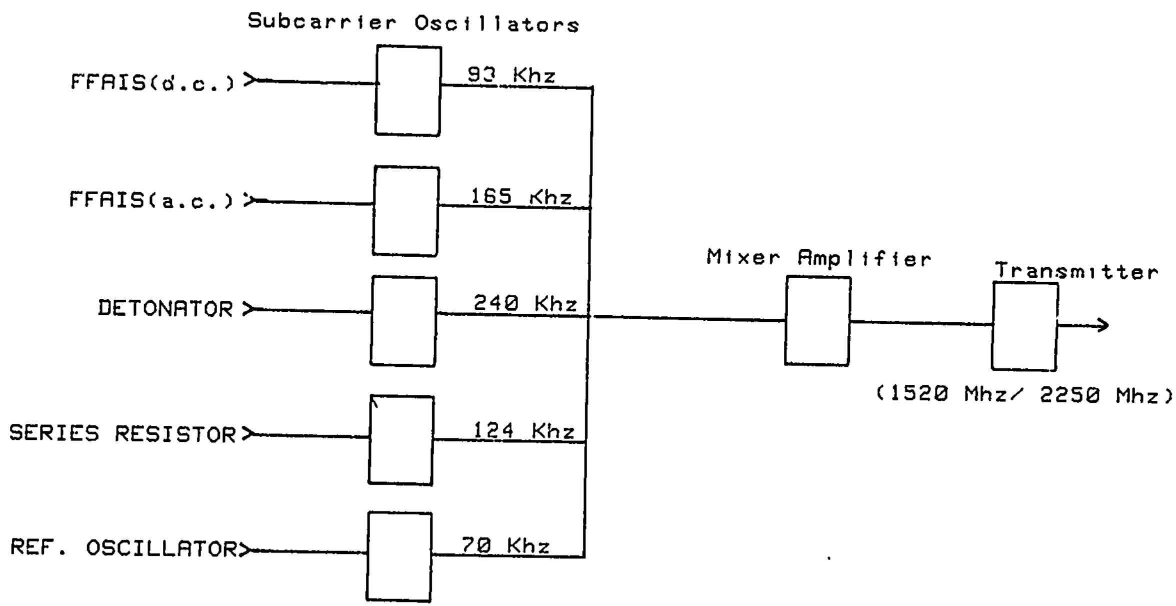

Figure 5. Schematic of the FM/FM telemeter circuit.

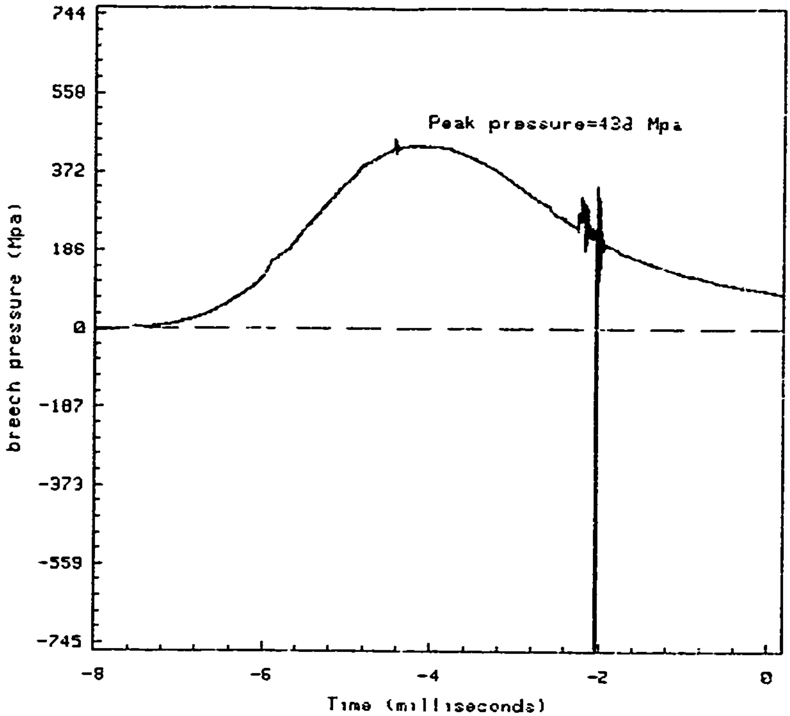

Figure 6. Breech pressure for E1-9942.

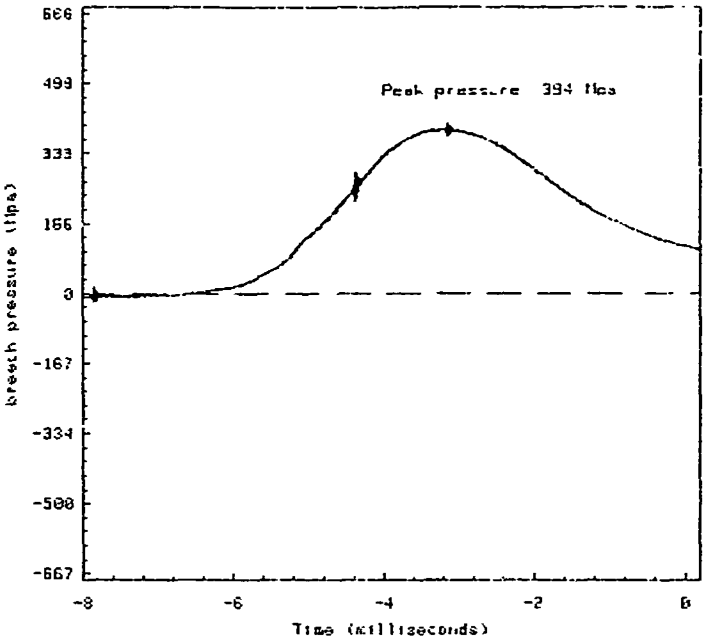

Figure 7. Breech pressure for E1-9943.

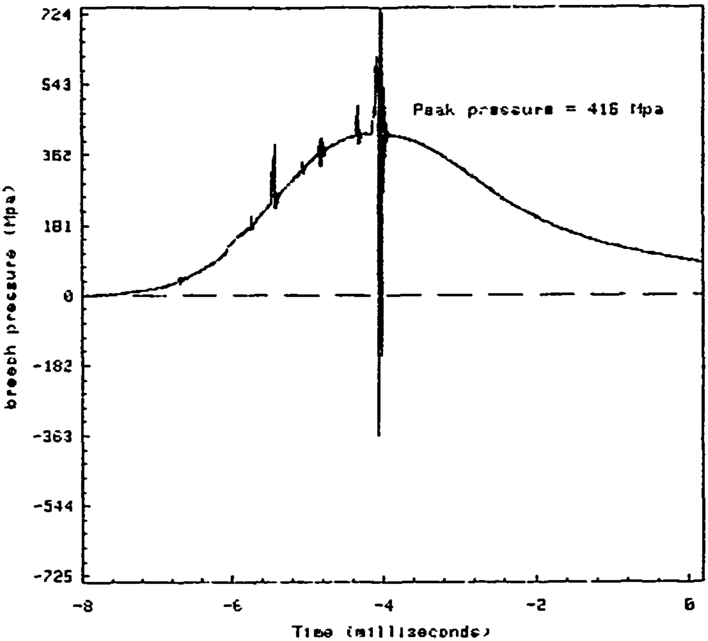

Figure 8. Breech pressure for E1-9944.

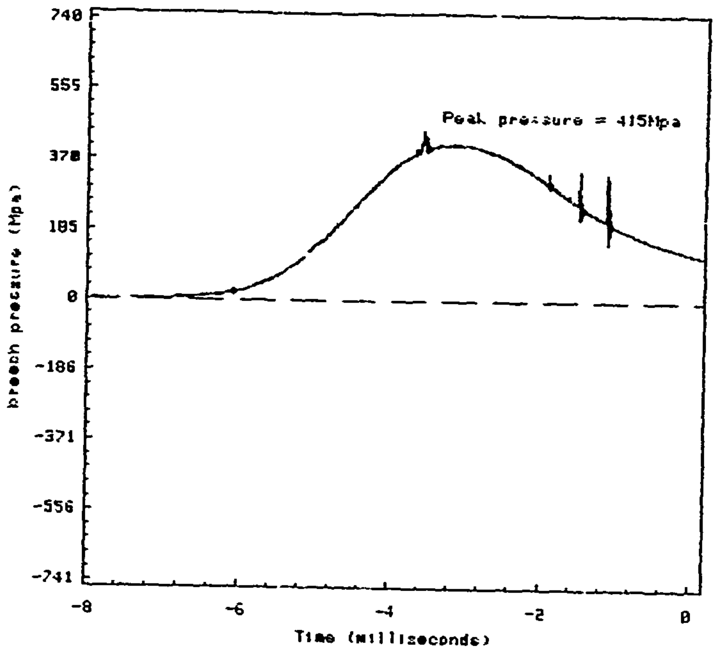

Figure 9. Breech pressure for E1-9945.

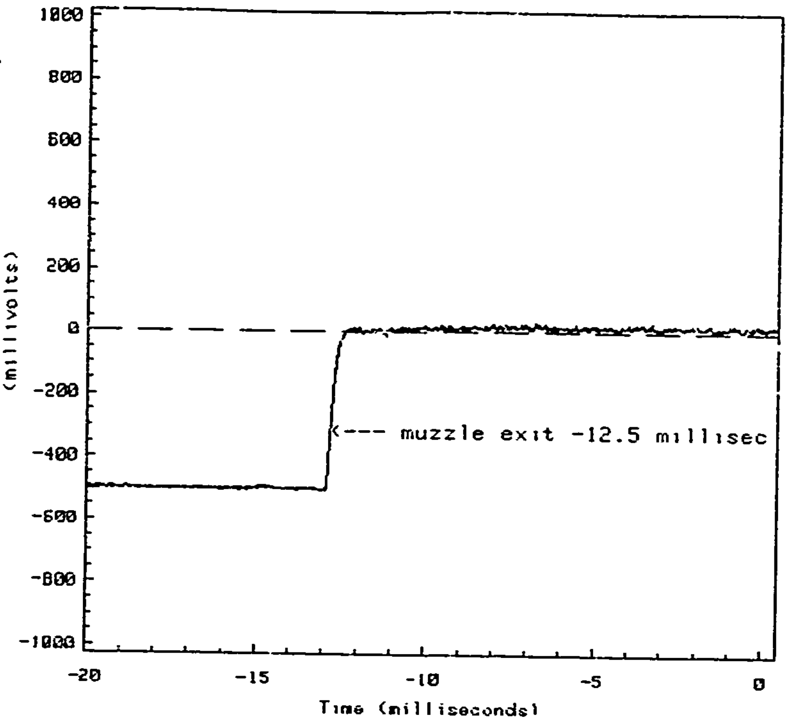

Figure 10. AGC signal for E1-9943.

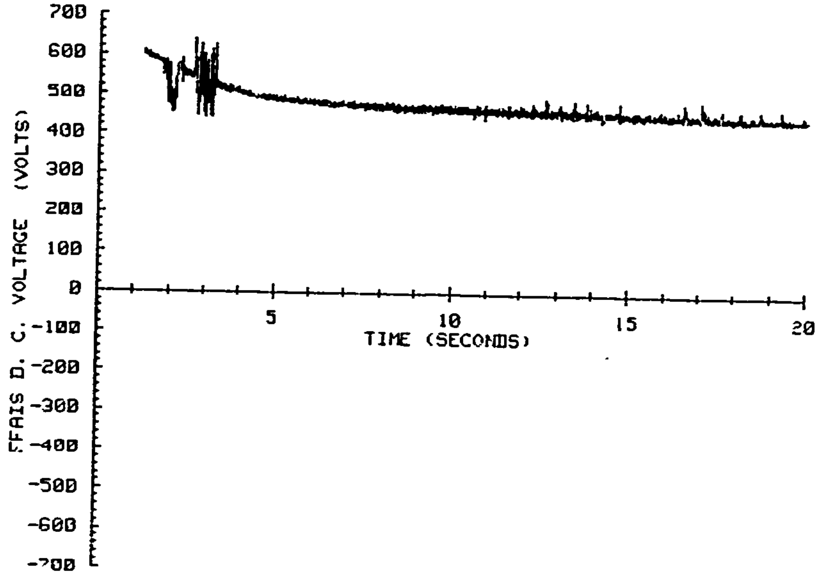

Figure 11. D.C. voltage across the FFAIS for E1-9944.

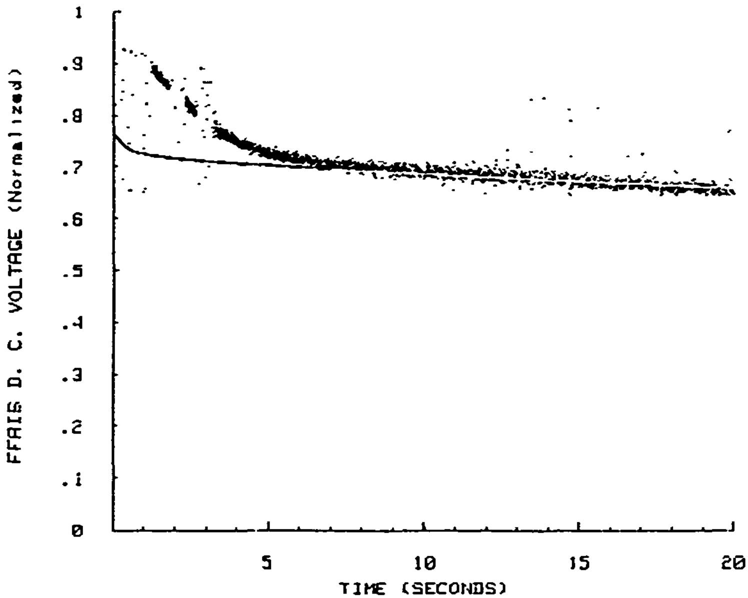

Figure 12. Comparison of decay of FFAIS voltage between flight data and pre-flight test data (E1-9944).

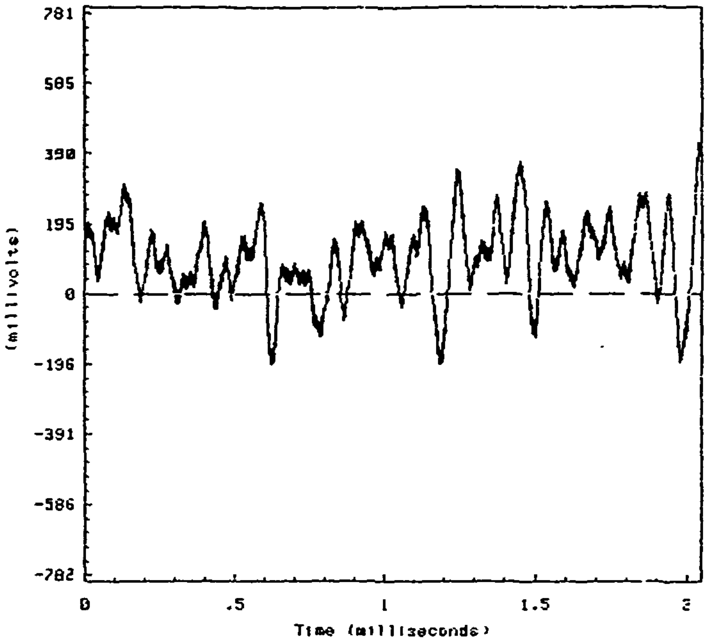

Figure 13. A.C. signals across the FFAIS for E1-9944 (Te + 1.26 sec).

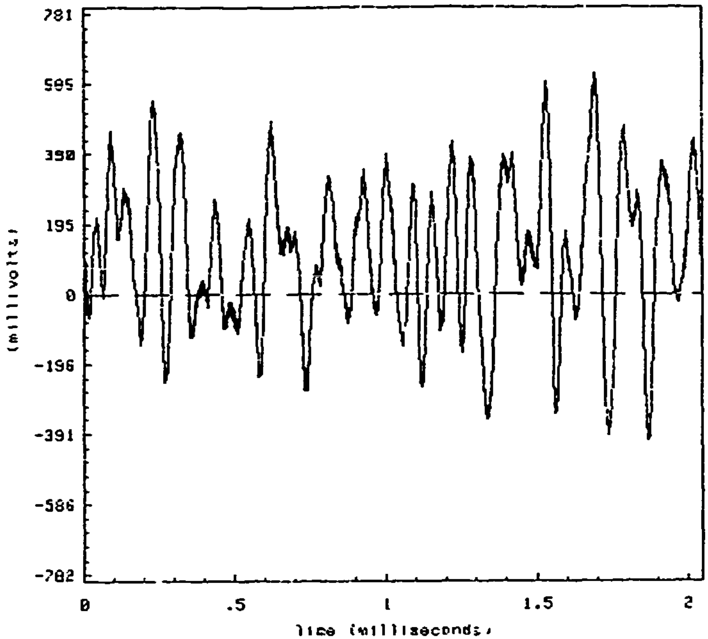

Figure 14. A.C. signals across the FFAIS for E1-9944 (Te + 10.1 sec).

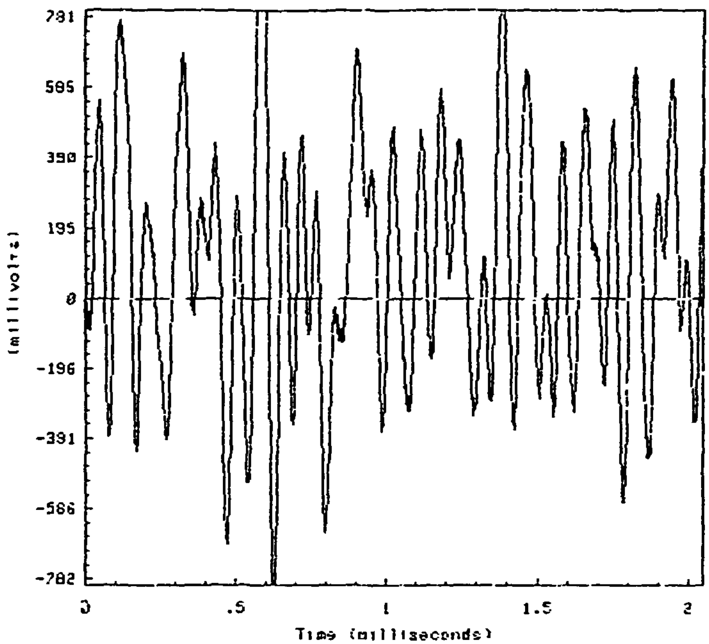

Figure 15. A.C. signals across the FFAIS for E1-9944 (Te + 20.1 sec).

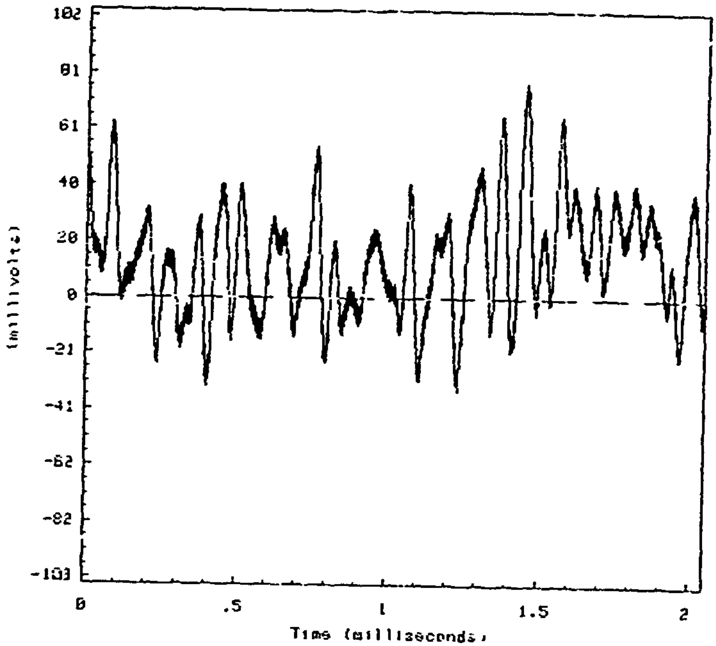

Figure 16. A.C. signals across the fuze for E1-9944 (Te + 1.26 sec).

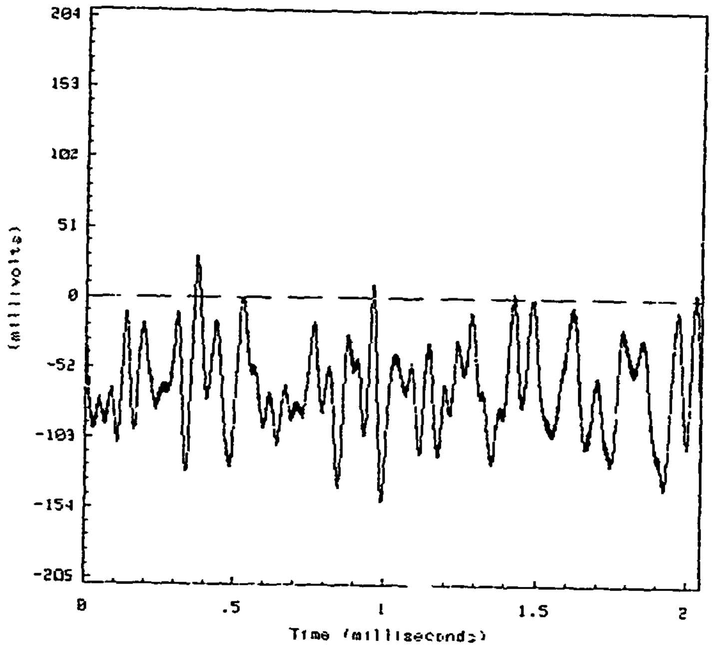

Figure 17. A.C. signals across the fuze for El-9944 (Te + 10.1 sec).

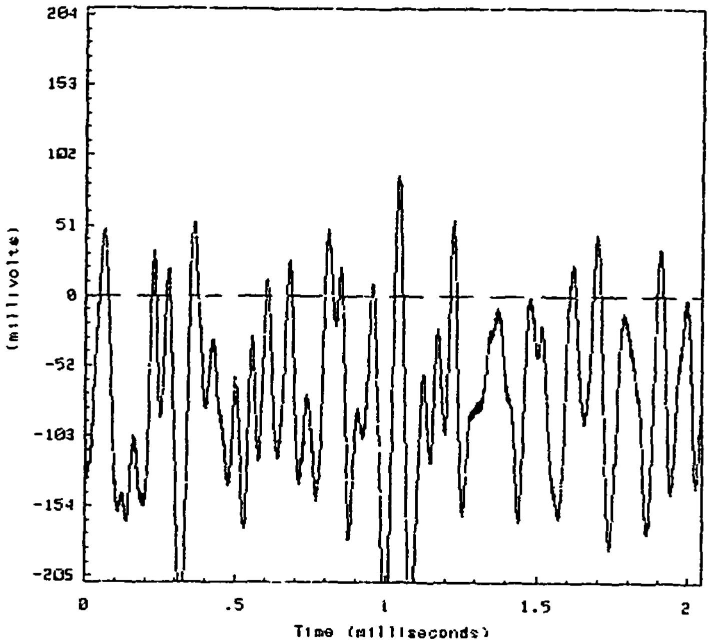

Figure 18. A.C. signals across the fuze for E1-9944 (Te + 20.1 sec).

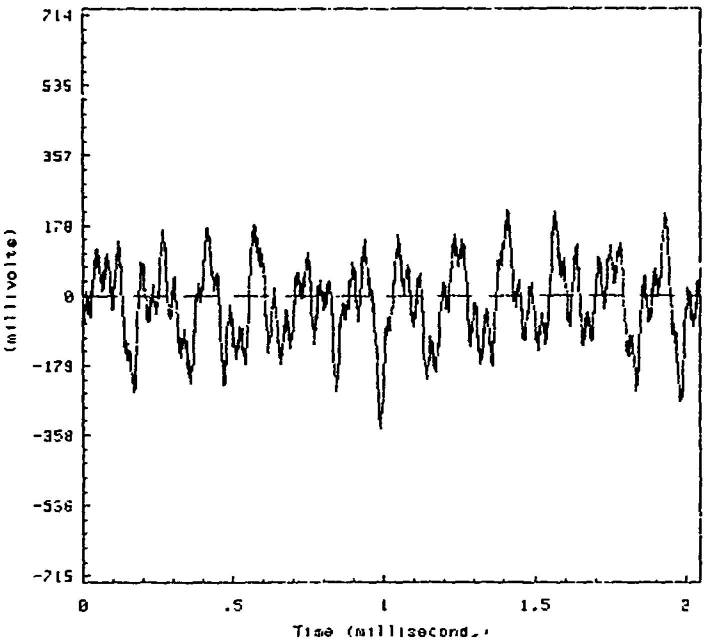

Figure 19. A.C. signals across 300 ohm series resistor for E1-9944 (Te + 1.26 sec).

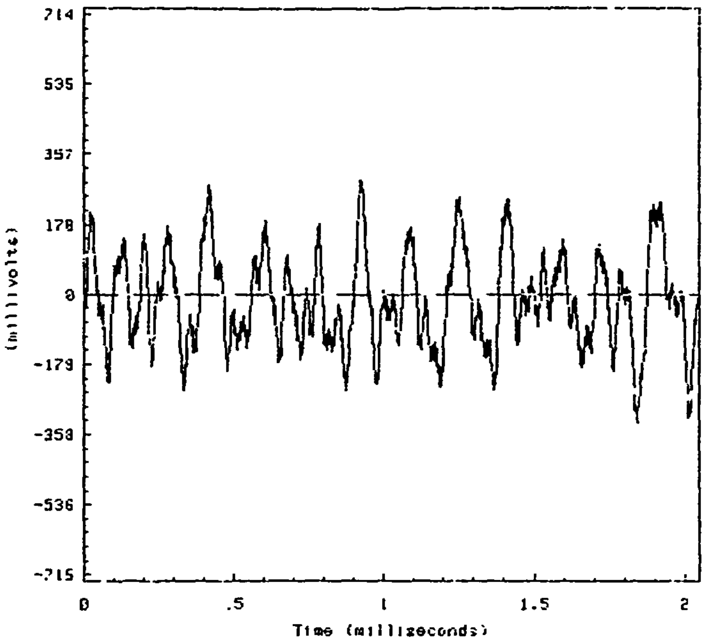

Figure 20. A.C. signal- across 300 ohm series resistor for E1-9944 (Te + 10.1 sec).

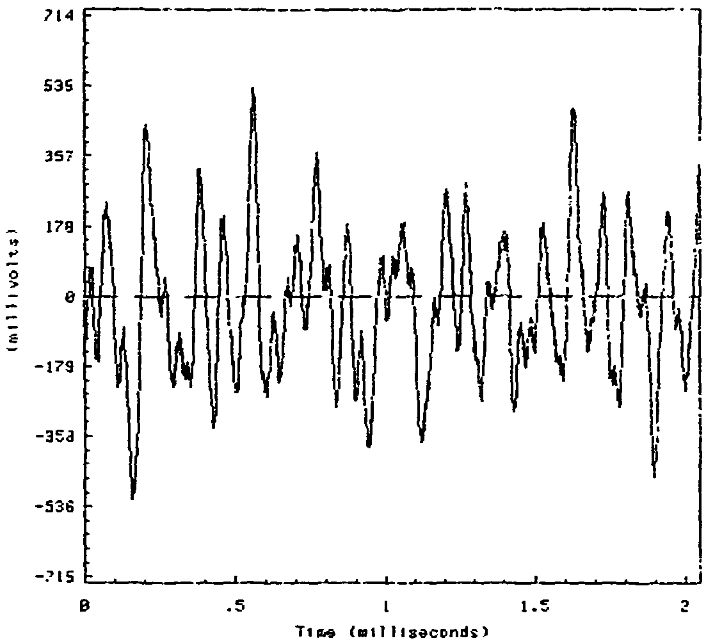

Figure 21. A.C. signals across 300 ohm series resistor for E1-9944 (Te + 20.1 sec).

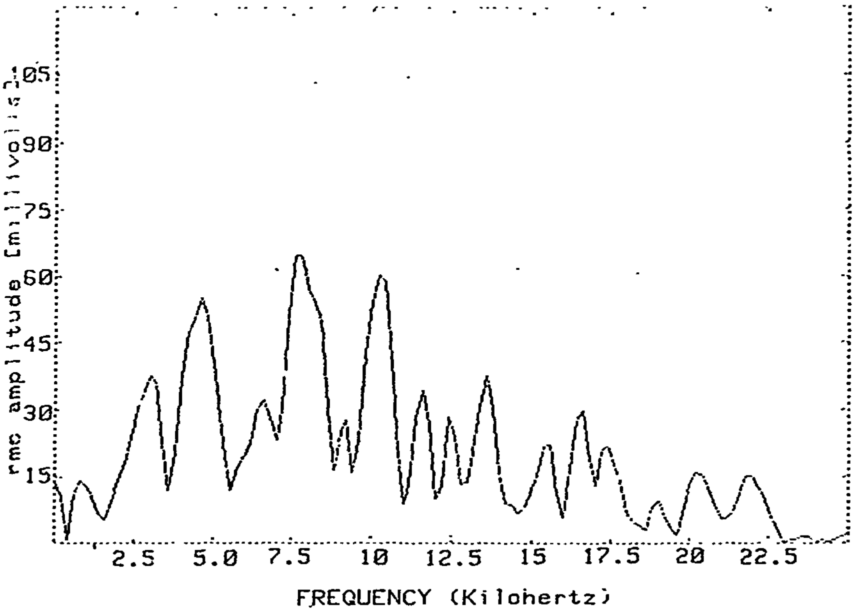

Figure 22. Frequency spectrum of signals across the FFAIS
for El-9944 (Te + 10.1 sec).

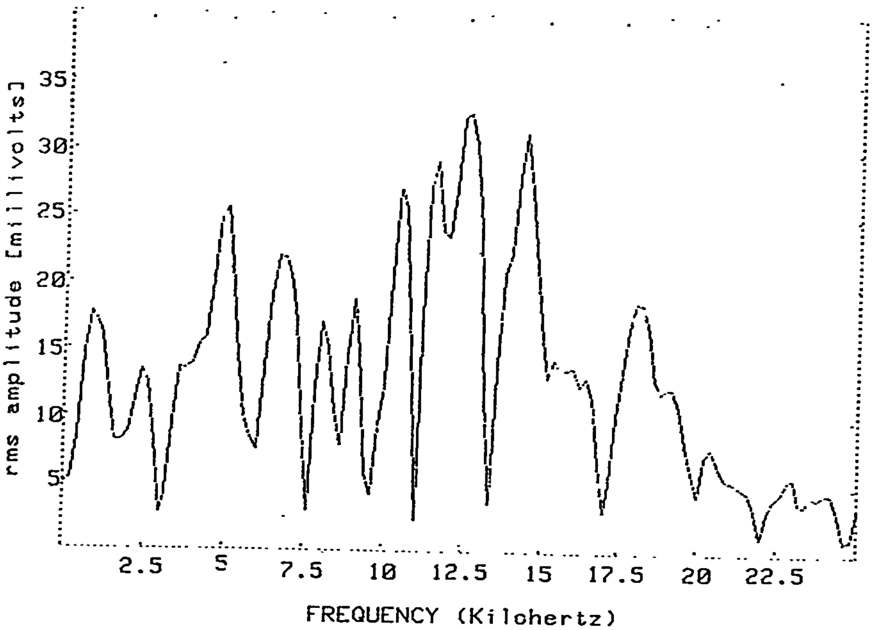

Figure 23. Frequency spectrum of signals across M509 fuze for El-9944 (Te + 10.1 sec).

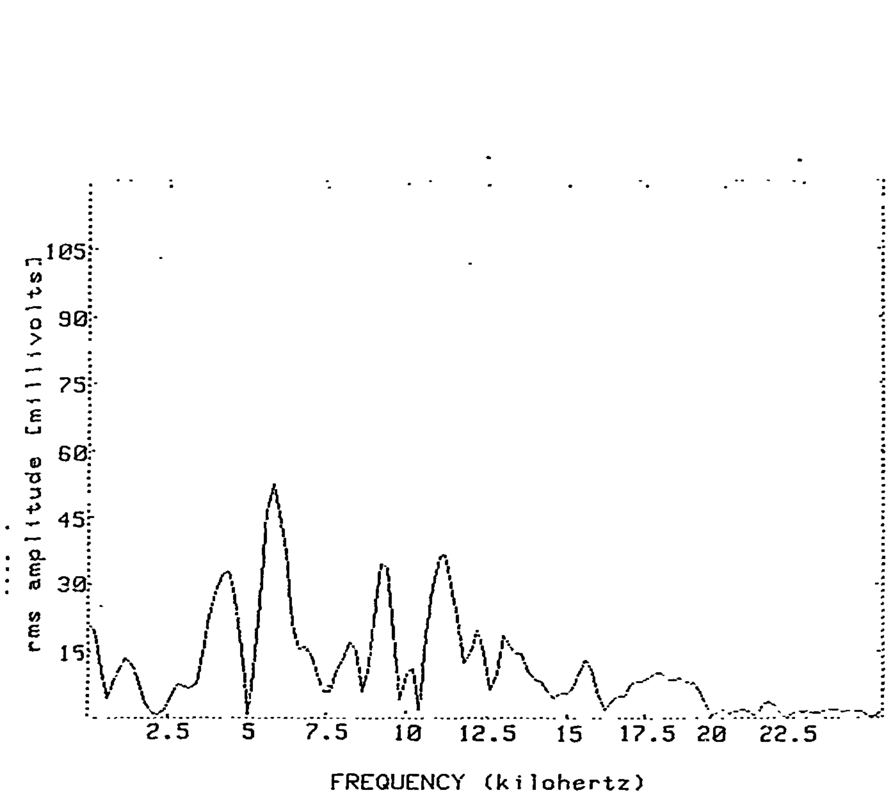

Figure 24. Frequency spectrum of signals across 300 ohm series resistor for E1-9944 (Te + 10.1 sec).

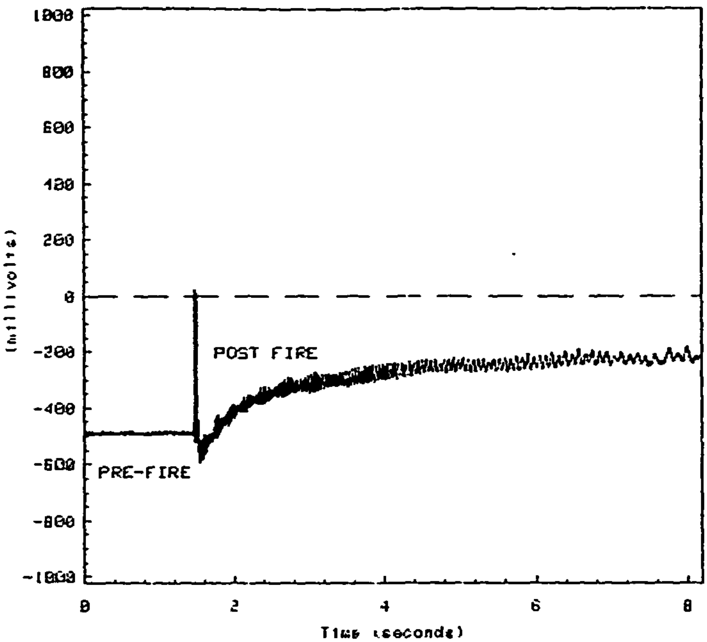

Figure 25. AGC signals for E1-9942.

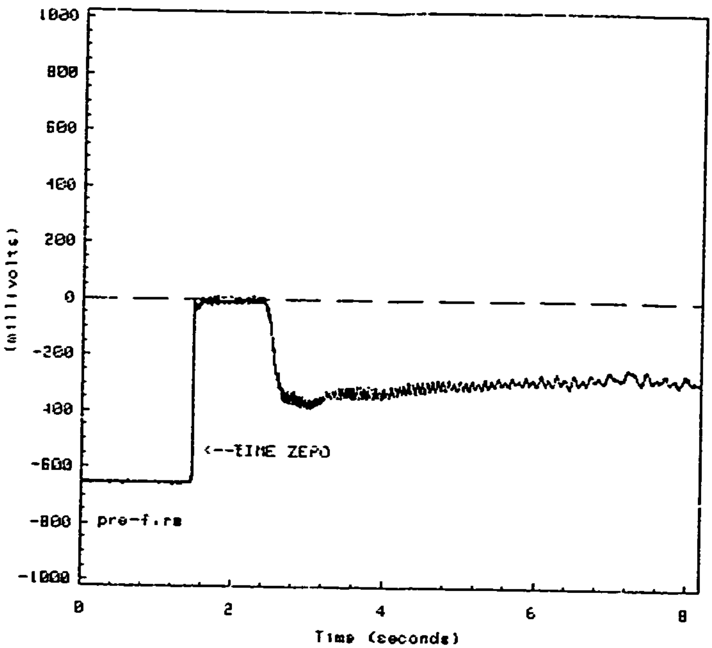

Figure 26. AGC signals for E1-9945.

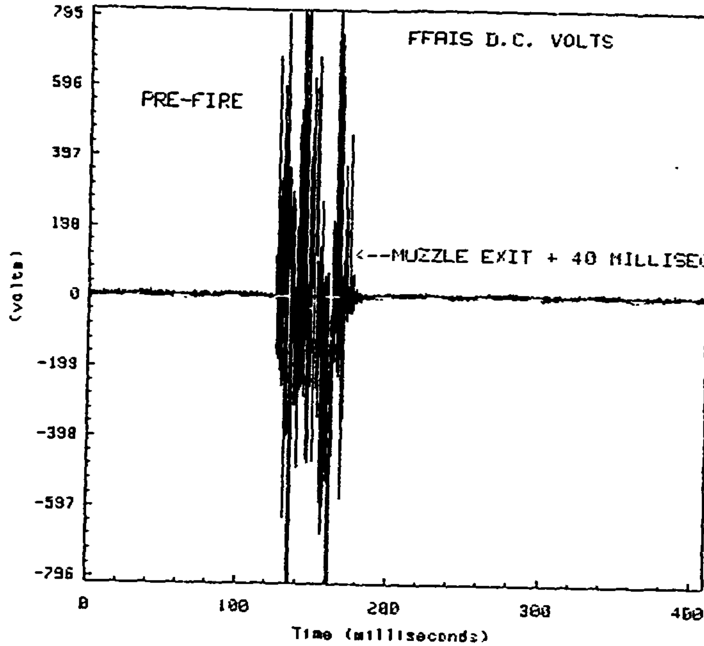

Figure 27. D.C. voltage across the FFAIS for E1-9942.

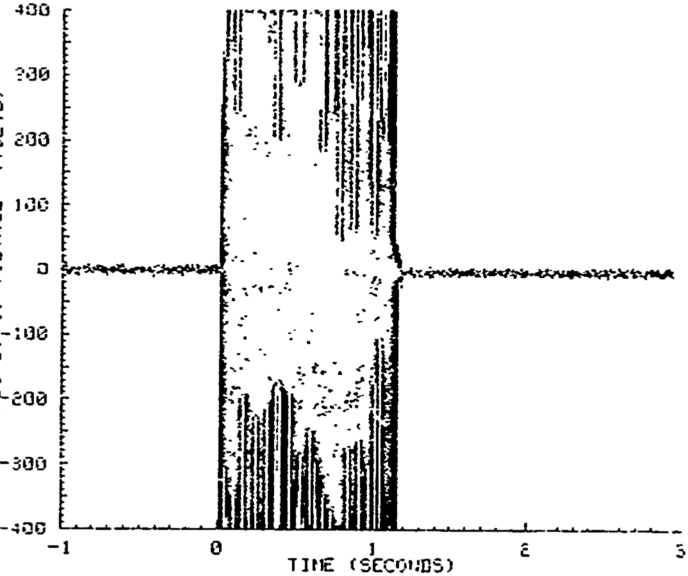

Figure 28. D.C. voltage across the FFAIS for EI-9945.

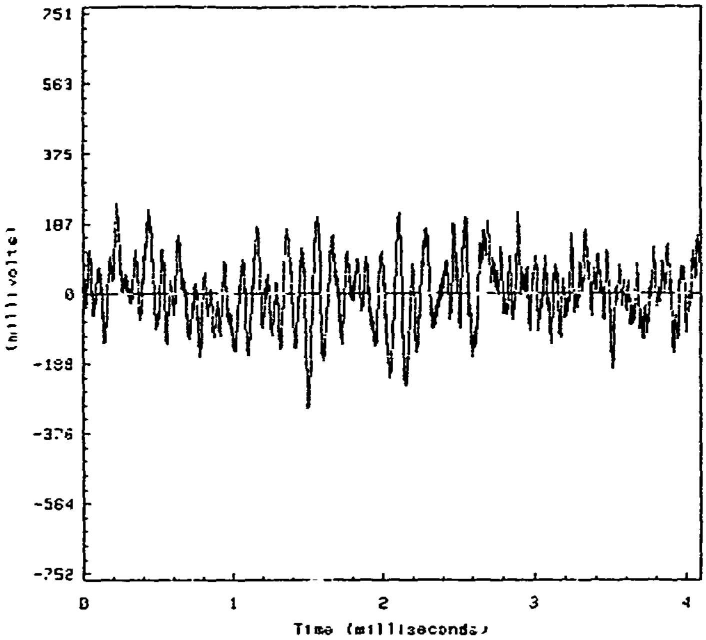

Figure 29. A.C. signals across the FFAIS for E1-9942 (Te + 1 sec).

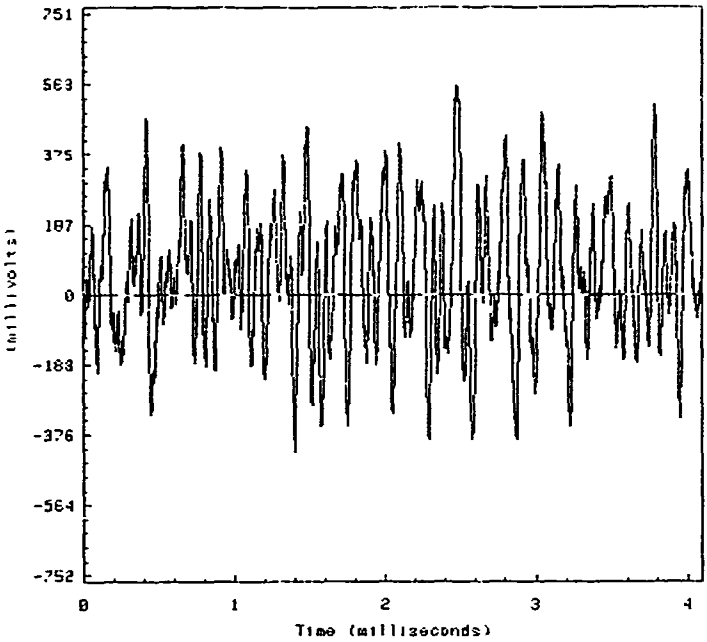

Figure 30. A.C. signals across the FFAIS for E1-9942 (Te + 5 sec).

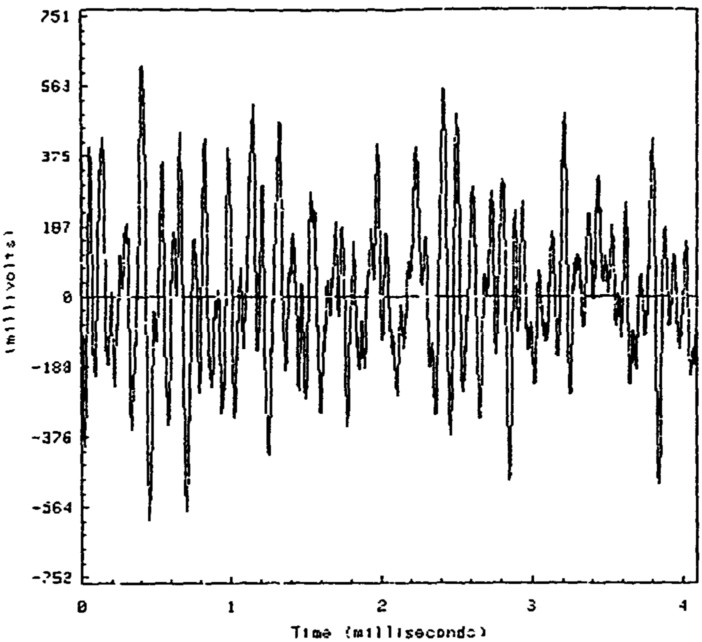

Figure 31. A.C. signals across the FFAIS for E1-9942 (Te + 10 sec).

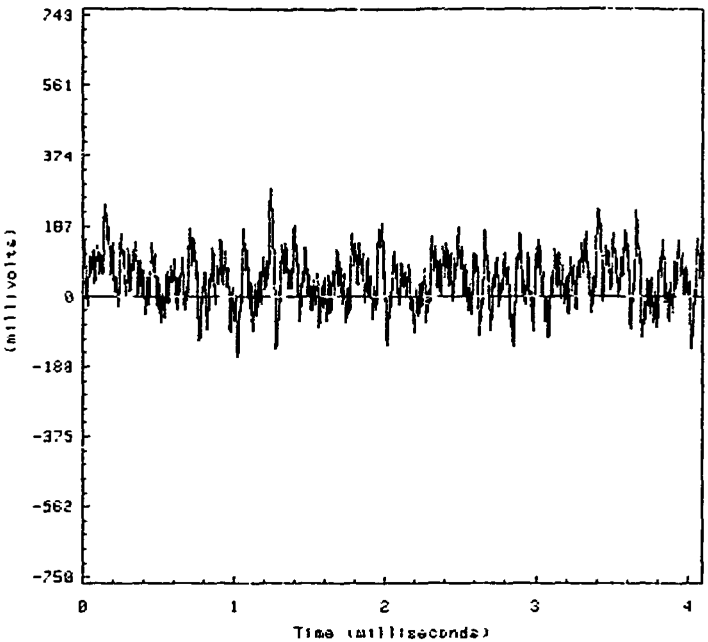

Figure 32. A.C. signals across the FFAIS for El-9945 (Te + 1.5 sec).

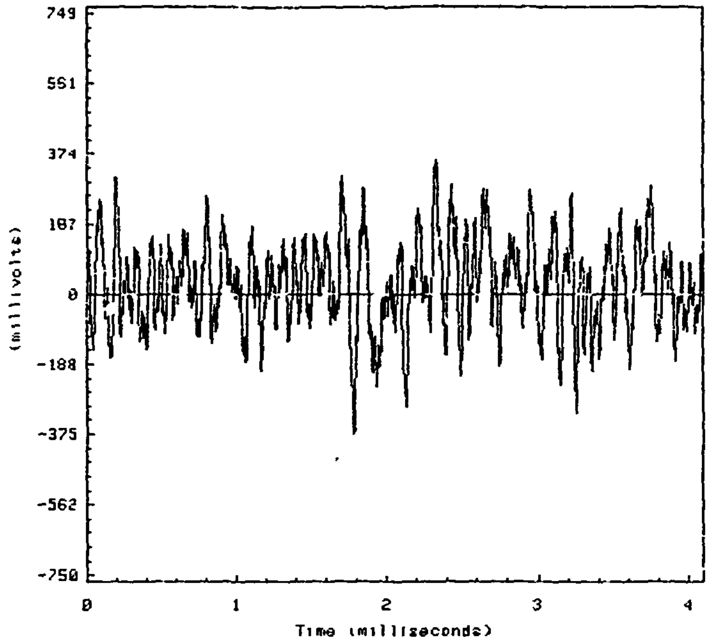

Figure 33. A.C. signals across the FFAIS for E1-9945 (Te + 5 sec).

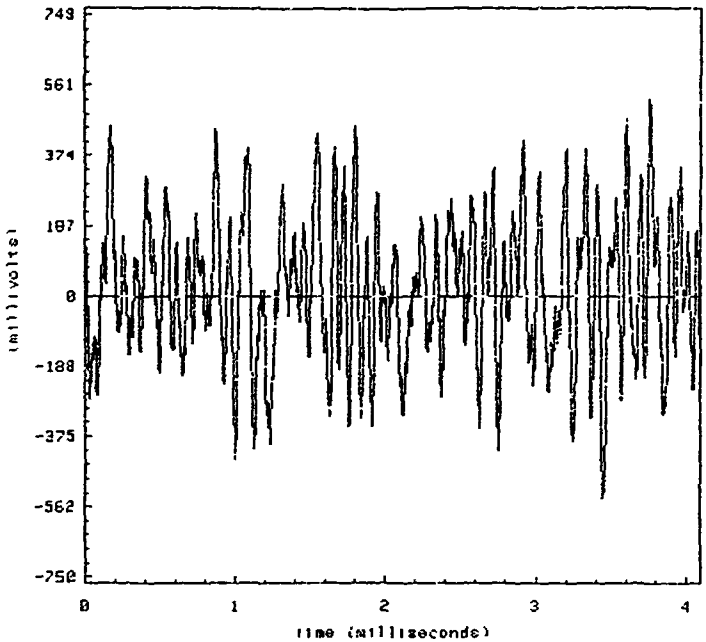

Figure 34. A.C. signals across the FFAIS for E1-9945 (Te + 10 sec).

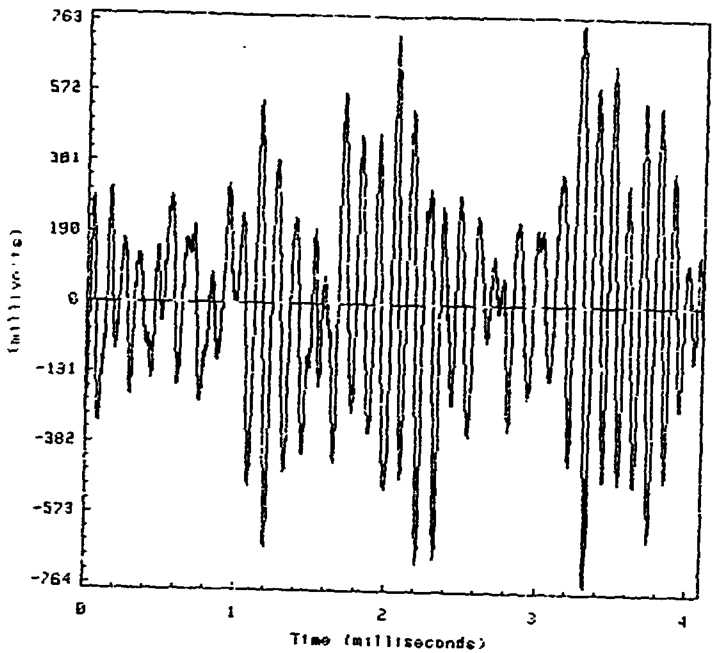

Figure 35. A.C. signals across M509 fuze for E1-9942 (Te + 1 sec).

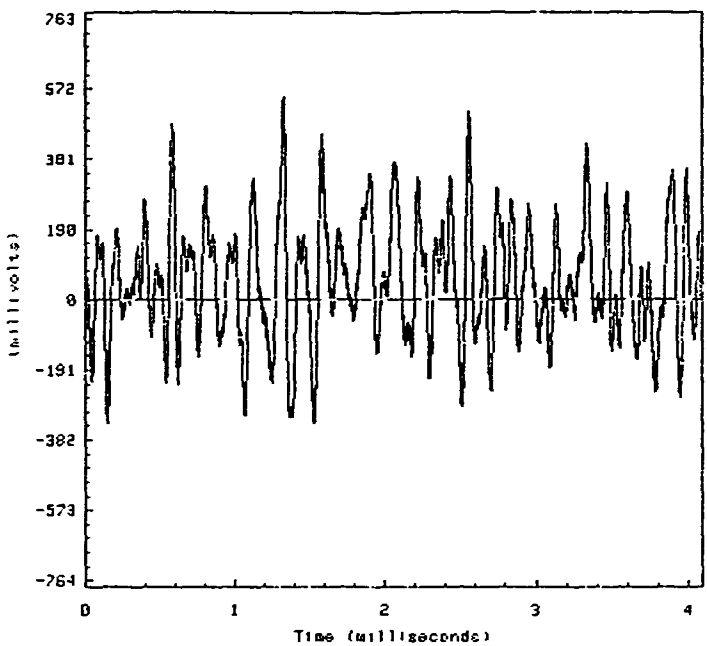

Figure 36. A.C. signals across M509 fuze for E1-9942 (Te + 5 sec).

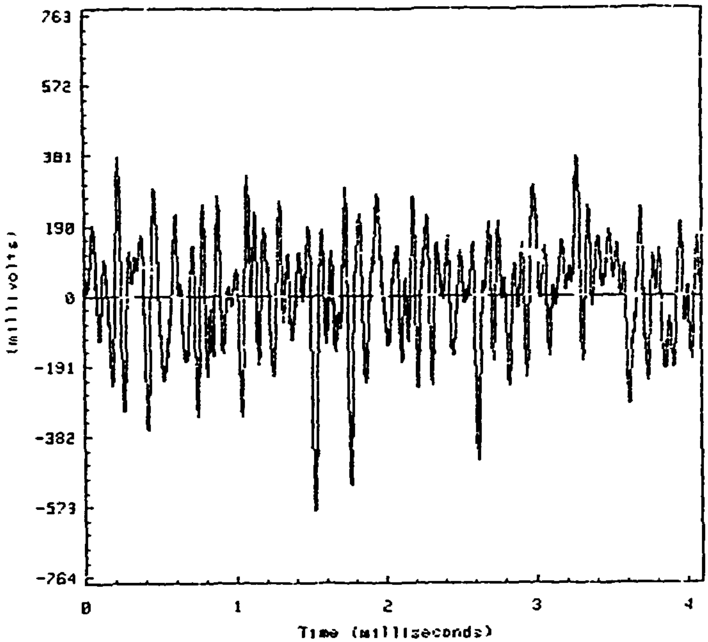

Figure 37. A.C. signals across M509 fuze for E1-9942 (Te + 10 sec).

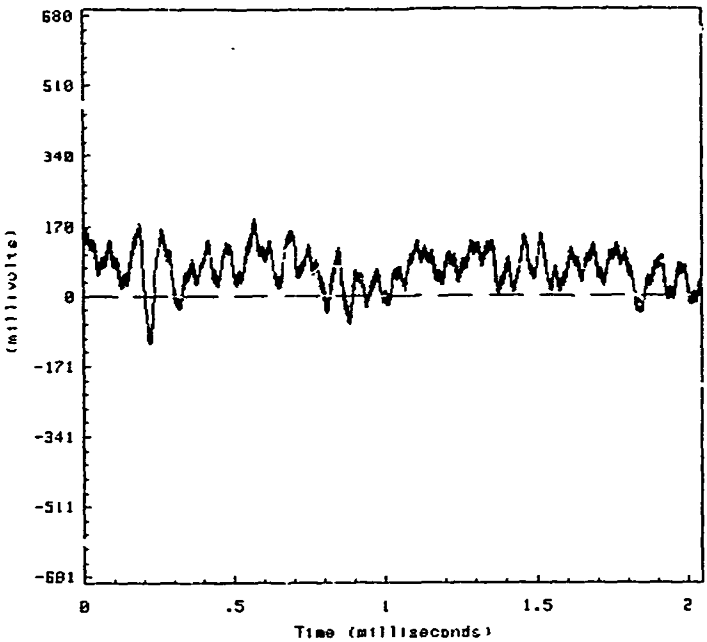

Figure 38. A.C. signals across M509 fuze for E1-9945 (Te + 1.5 sec).

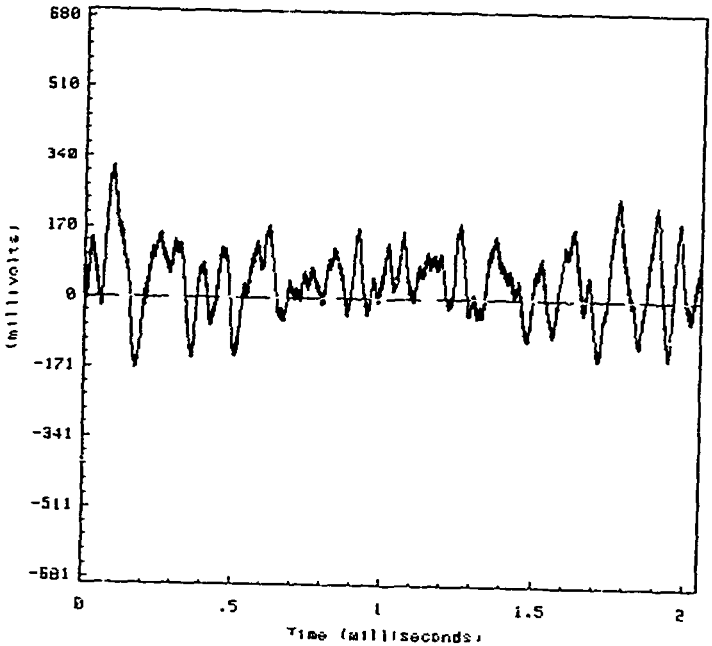

Figure 39. A.C. signals across M509 fuze for E1-9945 (Te + 5 sec).

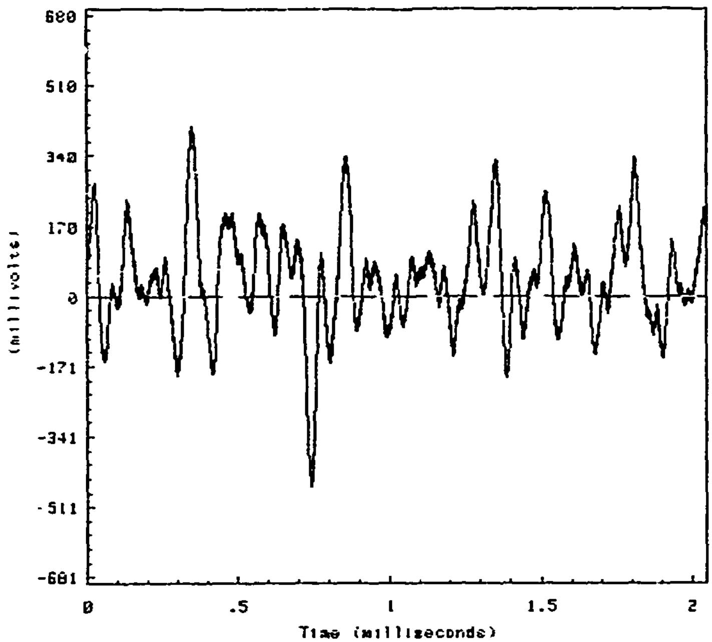

Figure 40. A.C. signals across M509 fuze for E1-9945 (Te + 10 sec).

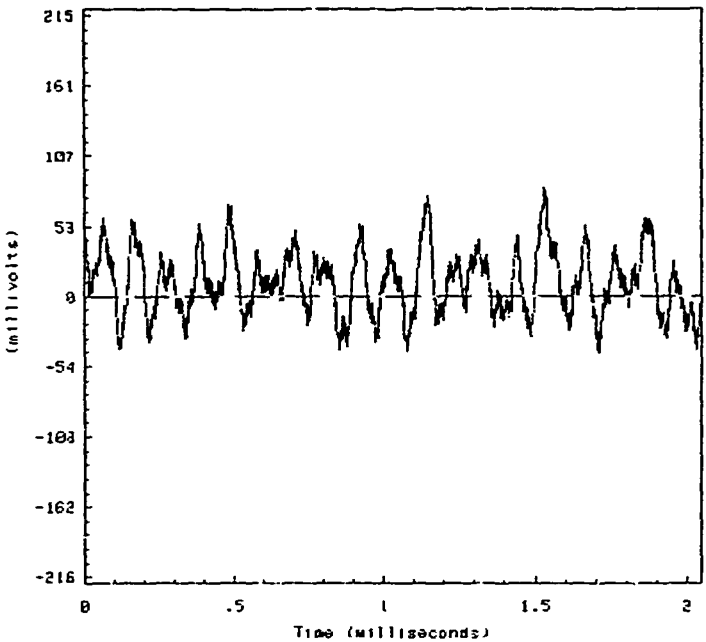

Figure 41. A.C. signals across 300 ohm series resistor for E1-9945 (Te + 1.5 sec).

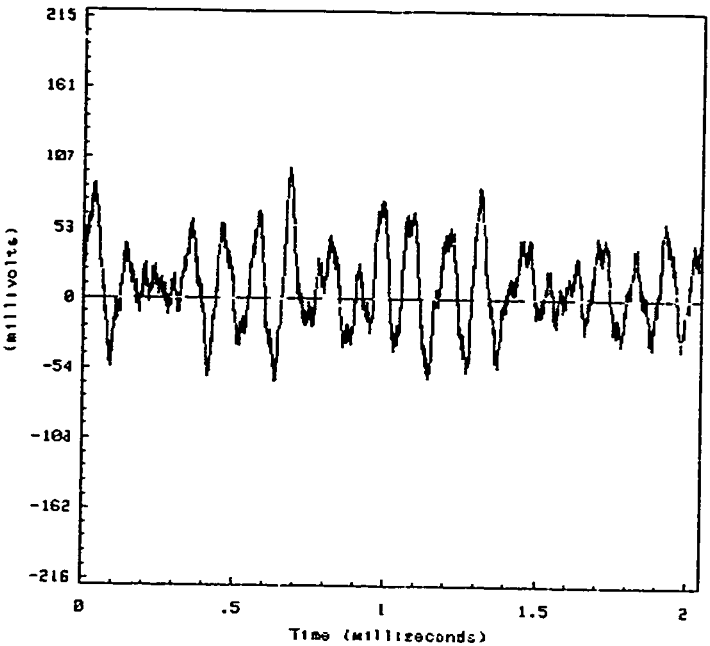

Figure 42. A.C. signals across 300 ohm series resistor for E1-9945
(Te + 5 sec).

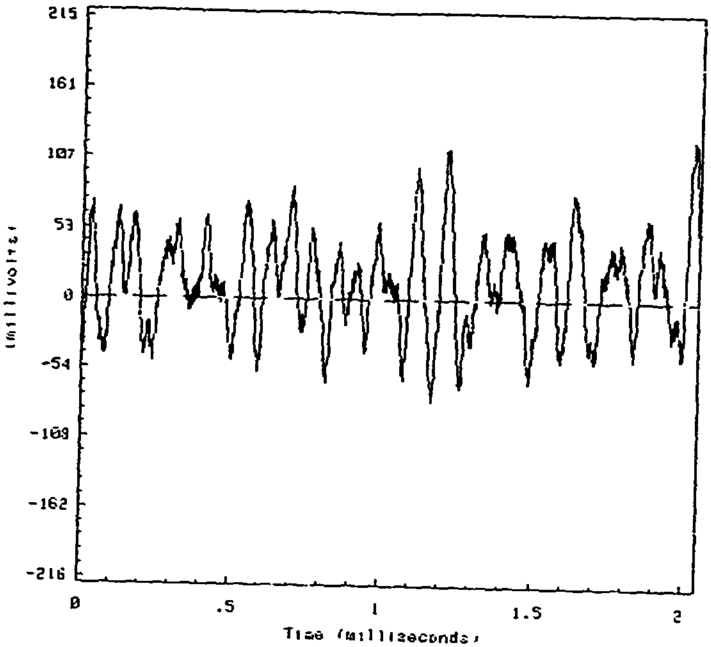

Figure 43. A.C. signals across 300 ohm series resistor for El-9945 (Te + 10 sec).

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